FRACTIONATION PATTERNS IN THE ATMOSPHERES OF TERRESTRIAL PLANETS: OBSERVATIONS, SIMULATIONS, AND MODEL CALCULATIONS. A. Weigel, K. Marti, and K. Ponganis, University of California at San Diego, Dept. of Chemistry 0317, La Jolla CA92093, U.S.A.

Many models on the evolution of planetary atmospheres use solar abundances as the starting composition. Hydrodynamic escape [1] and low-energy ion implantation [2,3] have both been proposed as mechanisms for elemental and isotopic fractionations. The latter has been tested in simulation experiments. We compare observed atmospheric compositions of the terrestrial planets with models invoking more than one fractionation step.

An issue central to the origin and evolution of the atmospheres of terrestrial planets is how, when, and from what sources the accreting planetesimals acquired their gaseous elements. Sources of atmospheric volatiles may include the solar nebula, the solar wind, comets, and asteroids.

The elemental abundance patterns of noble gases in Earth and Mars are similar, but isotopic signatures differ. While Xe in both atmospheres is strongly mass fractionated [4,5] the extent of the fractionation differs and the Ar isotopic signatures are distinct. In contrast Kr shows little fractionation relative to solar composition.

Several mechanisms for the incorporation of planetary atmospheric gases have been proposed; some of them have been modeled in detail. We consider gravitational capture of nebular gases, solar wind loading of accreting matter, adsorption on accreting grains, gas loading in a dusty plasma during accretion [2,3,6] to represent primary processes. Impact degassing by projectiles (comets, asteroids), Jeans escape, hydrodynamic escape [1], photochemical escape, and sputtering processes all modify primary atmospheres. All single-step models tested so far fail to explain all noble gas isotopic abundances when consistent evolutionary parameters and initial compositions are used.

Our low-energy ion implantation simulation experiments have shown that in acquisitions of a primary gas composition both the elemental and the isotopic patterns are fractionated.

One set of environmental conditions for the process of ion implantation are dusty plasmas. Neutral gas can also be implanted for energies of the order of tens of eV. Particle radiation from the T-Tauri stage of the Sun or neighboring stars, as well as gas from the local interstellar medium with todays velocities of 26km/s [7] implanted into accreting grains and planetesimals may be considered. Interplanetary dust particles exposed to solar UV radiation and the solar wind plasma are charged to surface potentials of ~3V, and the current plasma environments of Jupiter and Saturn lead to surface potentials of dust particles from -30V to +3V [6] (these dust grains are therefore also very suitable ion implantation sites).

Elemental abundance patterns (normalized to Ar) of noble gases in the atmospheres of the terrestrial planets relative to the solar abundances are shown in figure 1. Fig. 1 also shows that fractionation patterns due to low-energy ion implantation may account for the fractionation observed for Kr and Xe (relative to Ar) in the atmosphere of Venus, but not in the atmospheres of Earth and Mars. Ne in the atmospheres of the terrestrial planets is systematically lower than observed in ion implantation experiments in tungsten. Recent Ar, Kr, and Xe measurements of solar wind implanted into lunar grains also suggest that the abundances of solar Kr and Xe (relative to Ar) probably were higher than previously assumed [8]. This would affect the fractionation of Kr and Xe (relative to Ar). However, it appears that fractionation effects of low-energy ion implantation can be increased by substantial factors in realistic, low mass targets (O, Al, Si, and Fe).

Simultaneous matches of isotopic and elemental abundances can be achieved with constrained initial compositions [9]. We will present possible matches using two-step processes with uniform initial compositions.

References: [1] Hunten *et al.* (1987) Icarus 69, 532. [2] K. Ponganis *et al.* (1996) JGR, submitted. [3] T. Bernatowicz and B. Hagee (1987) GCA 51, 1599. [4] T. Swindle *et al.* (1986) GCA 50, 1001. [5] K. Mathew *et al.* (1997) LPSC 28, this volume. [6] M. Horanyi (1996) Annu. Rev. Astron. Astrophys. 34, 383. [7] M. Witte *et al.* (1993) Adv. Space Res. 13, No. 6, 121. [8] R. Wieler *et al.* (1996) Nature 384, 46. [9] R. Pepin (1992) Annu. Rev. Earth Planet. Sci. 20, 389.

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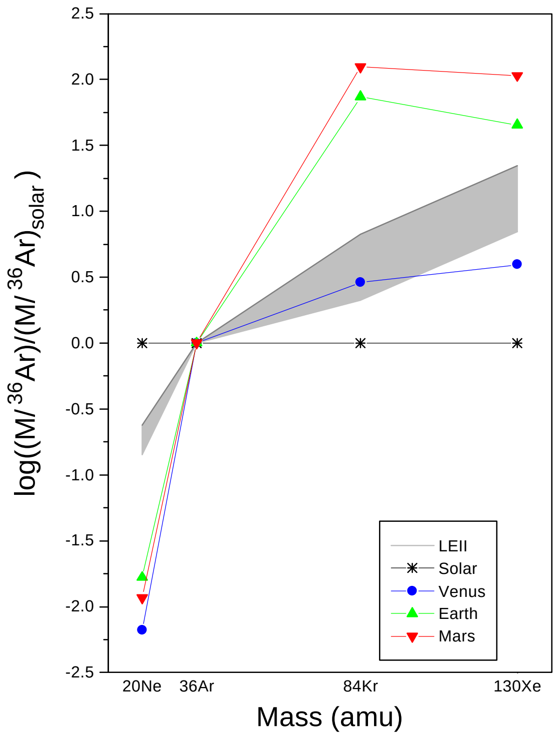

Fig. 1: Observed elemental abundance patterns (normalized to Ar) relative to solar composition are compared to the range of fractionations obtained in ion implantations into W [2,3].